

WHAT IS CLAIMED IS:

1. (Currently Amended) A control apparatus for an internal combustion engine, the internal combustion engine capable of a pre-mixed charge compression ignition combustion and having fuel injection means for injecting fuel into a combustion chamber defined by a cylinder and a piston, wherein air-fuel mixture gas including at least air and fuel injected by the fuel injection means is formed in the combustion chamber and the air-fuel mixture gas is self-ignited to be combusted by compressing the air-fuel mixture gas during a compression stroke, when a driving condition of the engine is within a self-ignition area, comprising:

temperature un-uniformity adding means for acting on the air-fuel mixture gas to enhance temperature un-uniformity of the air-fuel mixture gas at a predetermined acting timing which is within a middle phase of the compression stroke and prior to fuel pyrolysis starting timing, if the compression stroke is divided into an early phase of the compression stroke, the middle phase of the compression stroke, and a late phase of the compression stroke, the early phase of the compression stroke being a period in which mixing of the air-fuel mixture gas proceeds rapidly due to a turbulent flow in the combustion chamber, the middle phase of the compression stroke being a period in which the mixing of the air-fuel mixture gas proceeds relatively moderately and a the combustion reaction becomes more active gradually, and the late phase of the compression stroke being a period in which an explosive combustion reaction occurs, in such a manner that the temperature un-uniformity of the air-fuel mixture gas at the fuel pyrolysis starting timing which is within a compression stroke is made greater than temperature un-uniformity of the air-fuel mixture gas at the fuel pyrolysis starting timing obtained only by simply compressing the air-fuel mixture gas during the compression stroke, and so that the combustion is more moderate than combustion which occurs only by simply compressing the air-fuel mixture gas during the compression stroke.

2. The control apparatus according to claim 1, wherein said temperature un-uniformity adding means is configured so as to inject high pressure fluid into the air-fuel mixture gas at said predetermined acting timing to enhance the temperature un-uniformity of the air-fuel mixture gas.

3. The control apparatus according to claim 2, wherein said temperature un-uniformity adding means is configured so as to inject said high pressure fluid only when a driving condition of the internal combustion engine is within the self-ignition area and a load of the internal combustion engine is larger than a predetermined high load threshold.

4. (Currently Amended) The control apparatus according to claim 2 or claim 3, wherein said predetermined acting timing at which said temperature un-uniformity adding means injects said high pressure fluid is set in said middle phase of the compression stroke which is a period from a timing at which the temperature un-uniformity of the air-fuel mixture gas becomes minimum to a timing which precedes a predetermined crank angle prior to said fuel pyrolysis starting timing.

5. The control apparatus according to any one of claim 2 to claim 4, wherein said temperature un-uniformity adding means injects said high pressure fluid along a tangential direction of a bore of said cylinder.

6. The control apparatus according to any one of claim 2 to claim 5, wherein said high pressure fluid is high pressure air.

7. The control apparatus according to any one of claim 2 to claim 5, wherein said high pressure fluid is high pressure hydrogen or high pressure carbon monoxide.

8. The control apparatus according to anyone of claim 2 to claim 5, wherein said high pressure fluid is high pressure combustion gas which is compressed combustion gas after emitted from the combustion chamber.

9. The control apparatus according to any one of claim 2 to claim 5, wherein said high pressure fluid is high pressure water.

10. A control apparatus for an internal combustion engine,
the internal combustion engine including:

fuel injection means for injecting fuel into a combustion chamber defined
by a cylinder and a piston;

spark ignition means exposed to the combustion chamber; and

high pressure water injection means for injecting high pressure water into
the combustion chamber;

the engine being a 2-cycle engine that repeats an expansion stroke, an exhaust
stroke, a scavenging stroke, an intake stroke, and a compression stroke every 360° crank angle,
and being operated under either one of a pre-mixed charge self-ignition mode and a spark-
ignition mode,

wherein the engine is operated under the pre-mixed charge self-ignition mode if a
driving condition of the engine is within a self-ignition area, in which air-fuel mixture gas
including at least air and the fuel injected by the fuel injection means is formed in the combustion
chamber prior to the beginning of the compression stroke and the formed air-fuel mixture gas is
self-ignited to be combusted by being compressed during the compression stroke and,

wherein the engine is operated under the spark-ignition mode if the driving
condition of the engine is within a spark-ignition area which is an area other than said self-
ignition area, in which air-fuel mixture gas including at least air and the fuel injected by the fuel
injection means is spark-ignited by spark by said spark ignition means to be combusted after the
air-fuel mixture gas is compressed during the compression stroke;

the control apparatus comprising:

high pressure water injection control means

for injecting said high pressure water from said high pressure water
injection means at a predetermined acting timing within a compression stroke prior to a fuel
pyrolysis starting timing, if the operating mode of the engine is said pre-mixed charge self-
ignition mode, and

for injecting said high pressure water from said high pressure water
injection means during one of periods of the scavenging stroke, the intake stroke, and a period

which partially overlaps both of the scavenging stroke and the intake stroke, if the operating mode of the engine is said spark-ignition mode.

11. The control apparatus according to claim 10, wherein said high pressure water injection control means is configured so as to inject the high pressure water only when a load of the internal combustion engine is higher than a predetermined high load threshold if the operating mode of the engine is said pre-mixed charge self-ignition mode.

12. The control apparatus according to claim 10 or claim 11, wherein said high pressure water injection control means is configured so as to inject the high pressure water only when a load of the internal combustion engine is higher than a second predetermined high load threshold if the operating mode of the engine is said spark-ignition mode.

13. The control apparatus according to any one of claim 2 to claim 5, wherein said high pressure fluid is high pressure liquid fuel including alcohol which is harder to be self-ignited than the fuel.

14. A control apparatus for an internal combustion engine,
the internal combustion engine including:
fuel injection means for injecting fuel into a combustion chamber defined by a cylinder and a piston;
spark ignition means exposed to the combustion chamber; and
high pressure liquid fuel injection means for injecting into the combustion chamber high pressure liquid fuel including alcohol which is harder to be self-ignited than the fuel;
the engine being a 2-cycle engine which repeats an expansion stroke, an exhaust stroke, a scavenging stroke, an intake stroke, and a compression stroke every 360° crank angle, and being operated under either one of a pre-mixed charge self-ignition mode and a spark-ignition mode,

wherein the engine is operated under the pre-mixed charge self-ignition mode if a driving condition of the engine is within a self-ignition area, in which area fuel mixture gas including at least air and the fuel injected by the fuel injection means is formed in the combustion chamber prior to the beginning of the compression stroke and the formed air-fuel mixture gas is self-ignited to be combusted by being compressed during the compression stroke, and

wherein the engine is operated under the spark-ignition mode if the driving condition of the engine is within a spark-ignition area which is an area other than said self-ignition area, in which air-fuel mixture gas including at least air and fuel injected by the fuel injection means is spark-ignited by spark by said spark ignition means to be combusted after the air-fuel mixture gas is compressed during the compression stroke;

the control apparatus comprising:

high pressure liquid fuel injection control means for injecting said high pressure liquid fuel from said high pressure liquid fuel injection means at a predetermined acting timing within a compression stroke prior to a fuel pyrolysis starting timing, if the operating mode of the engine is said pre-mixed charge self-ignition mode, and for injecting said high pressure liquid fuel from said high pressure liquid fuel injection means during one of periods of the scavenging stroke, the intake stroke, and a period which partially overlaps both of the scavenging stroke and the intake stroke, if the operating mode of the engine is said spark-ignition mode.

15. The control apparatus according to claim 14, wherein said high pressure liquid fuel injection control means is configured so as to inject the high pressure liquid fuel only when a load of the internal combustion engine is larger than a first predetermined high load threshold if the operating mode of the engine is said pre-mixed charge self-ignition mode.

16. The control apparatus according to claim 14 or claim 15, wherein said high pressure liquid fuel injection control means is configured so as to inject the high pressure liquid fuel only when a load of the internal combustion engine is higher than a second predetermined high load threshold if the opening mode of the engine is said spark-ignition mode.

17. The control apparatus according to any one of claim 2 to claim 5, wherein said high pressure fluid is synthetic gas including carbon monoxide and hydrogen which are obtained by partially oxidizing the fuel.

18. The control apparatus according to any one of claim 2 to claim 4, wherein said temperature un-uniformity adding means is configured so as to inject said fuel as said high pressure fluid from said fuel injection means.

19. A control apparatus for an internal combustion engine,
the internal combustion engine including:
fuel injection means for injecting fuel into a combustion chamber defined by a cylinder and a piston;
spark ignition means exposed to the combustion chamber; and
high pressure fluid injection means for injecting high pressure fluid into the combustion chamber;
the engine being operated under either one of a pre-mixed charge self-ignition mode and a spark-ignition mode,
if a driving condition of the engine is within a self-ignition area, the engine being operated under the pre-mixed charge self-ignition mode in which air-fuel mixture gas including at least air and the fuel injected by the fuel injection means is formed in the combustion chamber prior to the beginning of a compression stroke and the formed air-fuel mixture gas is self-ignited to be combusted, and
if the driving condition of the engine is within a spark-ignition area which is an area other than said self-ignition area, the engine being operated under the spark-ignition mode in which air-fuel mixture gas including at least air and the fuel injected by the fuel injection means is spark-ignited by spark by said spark ignition means to be combusted after the air-fuel mixture gas is compressed during the compression stroke;
the control apparatus comprising:
high pressure fluid injection control means for injecting said high pressure fluid from said high pressure fluid injection means when crank angle reaches a predetermined crank

angle, if the operating mode of the engine is said pre-mixed charge self-ignition mode, and for injecting said high pressure fluid from said high pressure fluid injection means when crank angle reaches another predetermined crank angle different from said predetermined crank angle, if the operating mode of the engine is said spark-ignition mode.

20. The control apparatus according to claim 19, wherein said high pressure fluid injection control means is configured so as to inject the high pressure fluid only when a load of the internal combustion engine is larger than a first predetermined high load threshold if the operating mode of the engine is said pre-mixed charge self-ignition mode.

21. The control apparatus according to claim 19 or claim 20, wherein said high pressure fluid injection control means is configured so as to inject the high pressure fluid only when a load of the internal combustion engine is larger than a second predetermined high load threshold if the operating mode of the engine is said spark-ignition mode.

22. The control apparatus according to any one of claim 19 to claim 21, wherein said high pressure fluid is a fluid including any one of air, hydrogen, carbon monoxide, combustion gas which is compressed combustion gas after emitted from the combustion chamber, water, liquid fuel including alcohol, synthetic gas including carbon monoxide and hydrogen which are obtained by partially oxidizing the fuel, and said fuel.

23. A control apparatus for an internal combustion engine, the internal combustion engine capable of a pre-mixed charge compression ignition combustion and having a fuel injection means for injecting fuel into a combustion chamber defined by a cylinder and a piston, wherein air-fuel mixture gas including at least air and fuel injected by the fuel injection means is formed in the combustion chamber prior to beginning of a compression stroke and the air-fuel mixture gas is self-ignited to be combusted by compressing the air-fuel mixture gas during the compression stroke, when a driving condition of the engine is within a self-ignition area;

the control apparatus comprising:

fuel injection control means

for injecting from said fuel injection means a part of fuel of an fuel amount required by the engine prior to the beginning of the compression stroke and injecting from said fuel injection means the rest of the fuel of the amount required by the engine at a predetermined timing within the compression stroke prior to a fuel pyrolysis starting timing of said injected fuel, if a load of the engine is in a high load area where the load is higher than a high load threshold,

for injecting from said fuel injection means all of fuel of the fuel amount required by the engine prior to the compression stroke, if the load of the engine is in a middle load area where the load is higher than a middle load threshold which is lower than said high load threshold, and

for injecting from said fuel injection means all of fuel of the fuel amount required by the engine during the compression stroke, if the load of the engine is in a low load area where the load is lower than said middle load threshold.

24. A control apparatus for an internal combustion engine having fuel injection means for injecting fuel into a combustion chamber defined by a cylinder and a piston, the engine being a 2-cycle engine that repeats an expansion stroke, an exhaust stroke, a scavenging stroke, an intake stroke, and a compression stroke every 360° crank angle, wherein air-fuel mixture gas including at least air and fuel injected by the fuel injection means is formed in the combustion chamber prior to beginning of the compression stroke, and the air-fuel mixture gas is self-ignited to be combusted by compressing the air-fuel mixture gas during the compression stroke, when a driving condition of the engine is within a self-ignition area, comprising:

fuel injection control means

for injecting from said fuel injection means a part of fuel of an fuel amount required by the engine during one of periods of the scavenging stroke, the intake stroke, and a period which partially overlaps both of the scavenging stroke and the intake stroke, and injecting from said fuel injection means the rest of the fuel of the amount required by the engine at a predetermined timing within the compression stroke prior to a fuel pyrolysis starting timing of said injected fuel, if a load of the engine is in a high load area where the load is higher than a high load threshold,

for injecting from said fuel injection means all of fuel of the fuel amount required by the engine during one of periods of the scavenging stroke, the intake stroke, and a period which partially overlaps both of the scavenging stroke and the intake stroke, if the load of the engine is in a middle load area where the load is higher than a middle load threshold which is lower than said high load threshold, and

for injecting from said fuel injection means all of fuel of the fuel amount required by the engine during the compression stroke, if the load of the engine is in a low load area where the load is lower than said middle load threshold.

25. (New) The control apparatus according to any one of claim 1 to claim 9, wherein said temperature un-uniformity adding means changes said predetermined acting timing based on a load of the engine and a engine rotational speed.